DEVELOPMENT OF HYDROPHILIC HOLLOW FIBER FILTER AND ITS APPLICATION TO NUCLEAR POWER PLANTS

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ABSTRACT

The easily handleable Hollow Fiber Filter (HFF) has been developed by giving hydrophilic properties to the conventional HFF which has been widely used in nuclear power plants in Japan. This hydrophilic HFF has derivatively shown lower initial differential pressure (ΔP) and slower rising rate of ΔP than the conventional HFF. This effect is thought to be attributed to an increase in effective filter area and a decrease in contact resistance between the filter and water.

INTRODUCTION

The HFF has been extensively used in industry and general livelihood to remove suspended solids in water. The reason for this is due to the excellent separation ability and noelution of impurities into water. The HFF adopted in Toshiba additionally has the following features:

1. High strength and flexibility, because it is made from polyethylene and very thin.
2. An extensive filter area in a small space due to the fine filter diameter.
3. Differential pressure is easily recovered by the back-wash operation, due to the small filter pore ($<0.1\mu m$).

When applying HFF which has these features to nuclear power plants, it is necessary to consider the following three peculiarities.

The first of these requires high reliability, the second requires a large processing capacity and the third requires minimal generation in secondary wastes. Thus the HFF has gained high reliability from long-time production and use. The problem regarding a large processing capacity, involving the opposite problem about increasing the filter area scale and the filter pressure loss, has been solved by using the module-type filter. No secondary wastes are generated from the HFF system, because of the non-precoat type.

Although Toshiba's HFF has already been installed in some condensate polishing systems and radwaste systems on nuclear power plants in Japan and have shown excellent operational results (1,2,3,4), it was desired to handle the HFF module more easily. Because of the hydrophobic characteristics of this polyethylene-made HFF, it is necessary for the module to be immersed in alcohol before use and to be kept in water and to deal with this condition for storage and transportation.

This paper describes the development of an easily handleable HFF and its application to nuclear power plants.

HYDROPHILIC HOLLOW FIBER FILTER PREPARATION

Table I shows the conventional HFF specifications. HFF consists of polyethylene tubes and has hydrophobic characteristics. Each hollow is 0.3mm in diameter and has a lot of pores,whose sizes are approximately $0.1\mu m$, in the wall of the tubes. The procedure of hydrophilic HFF preparation is as follows.

TABLE I

HFF Specification

Material	Polyethylene
Hollow fiber diameter	approx. 0.3mm
Pore size	approx. $0.1\mu m$
Max. ΔP for use	$3\ Kg/cm^2$
Max. temperature for use	343 K
Characteristics	flexible
	durable

Hydrophilic substance, acrylic monomer, is impregnated in the HFF, and then polymerizes. After this treatment, the homogeneous and highly hydrophilic layer is formed on the filter surface involving inside pores. Figure 1 shows a diagram of this hydrophilic process.

The hydrophilic process improves the HFF handling considerably. While the conventional HFF module was placed in a cylindrical plastic case containing water and handled under these conditions for storage and transportation, the hydrophilic HFF module is contained in a film bag with a small amount of water and then packed in a corrugated cardboard box. The package weight of a module is reduced to one-third. (Conventional:15 Kg, Hydrophilic: 5Kg)

Though this hydrophilic HFF can originally be handled in the dry state, the reason to immerse it in a small amount of water is to eliminate the water circulating process in the vessel.

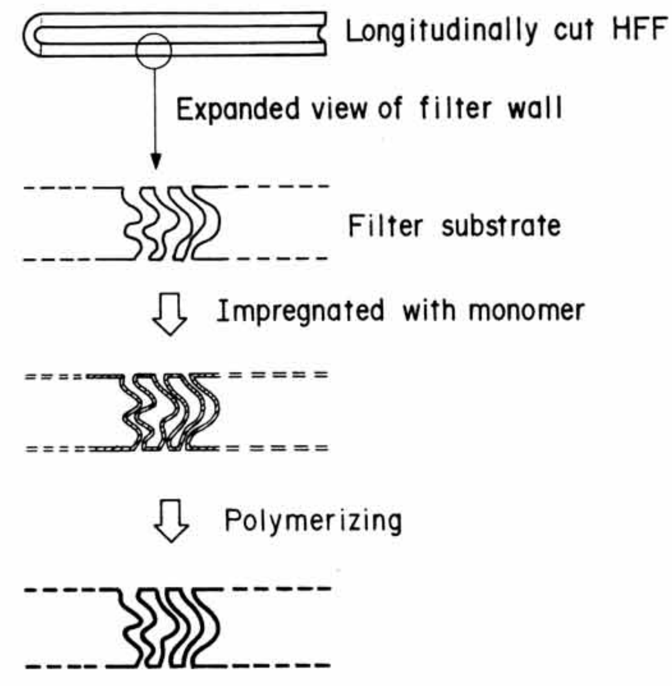

Fig. 1. Hydrophilic process diagram.

FLOW CHARACTERISTICS

The differential pressure (ΔP) variation in the conventional and hydrophilic HFF was investigated using a pilot scale apparatus. The test conditions were as follows:

1. Filter area $13m^2$
2. Linear velocity 0.1m/hr
3. Inlet pressure $7Kg/cm^2$

Figure 2 shows ΔP-time characteristics for individual filters. As shown in this figure, the hydrophilic HFF has low initial ΔP compared with the conventional HFF (Hydrophilic:approx. $0.3Kg/cm^2$, Conventional:approx. $0.4Kg/cm^2$) and slower rising rate. Figure 3 shows the inlet and outlet concentration of suspended Fe in waste water of both HFFs, outlet Fe concentrations were far lower than inlet.

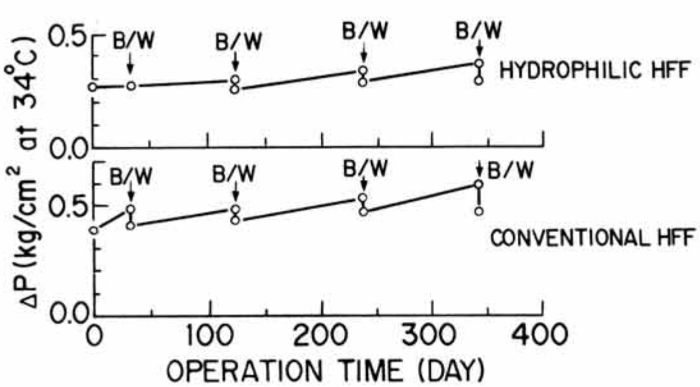

Fig. 2. Variation of ΔP with operation time.

The reason for having a low initial value and slow rising rate of ΔP is considered in the following in some detail. Figure 4 shows aggregation state for conventional and hydrophilic HFFs in water. As shown in this figure, the hydrophilic HFF filament dispersed in water, while the

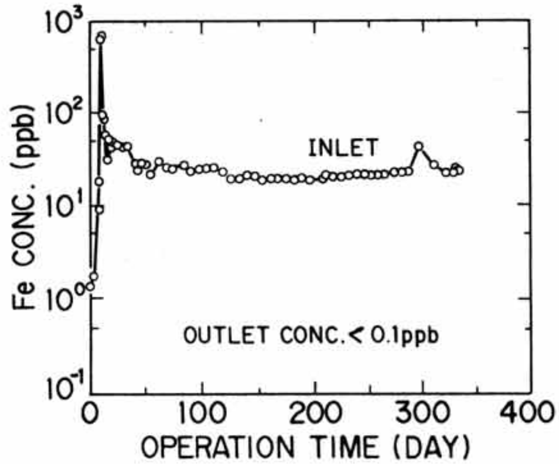

Fig. 3. Removal of suspended Fe with hydrophilic HFF.

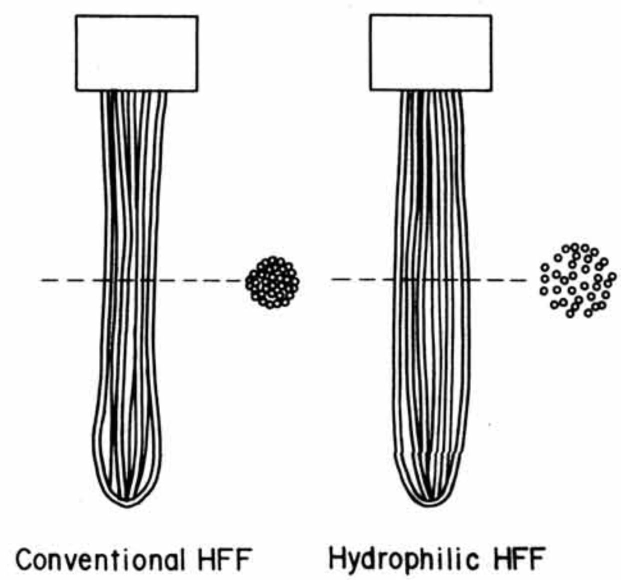

Fig. 4. Aggregation state in water.

conventional HFF filaments were in contact with each other, such as an oil droplet in water. This dispersion observed in hydrophilic HFF arises from decreasing the surface tension against water. Thus, the hydrophilic HFF has been effectively used with its actual filter area, while that for the conventional HFF has lowered by this contact. As the result of these aggregation states, these HFFs have different ΔP values.

APPLICATION TO NUCLEAR POWER PLANTS

The conventional HFF, which has shown excellent operational results in the condensate polishing system on Fukushima Daiichi Nuclear Power Station Unit No.3 (TEPCO 1F-3) for about four years and needed replacement, was replaced by the hydrophilic HFF. Table II shows the specifications of this system (5). It has HFFs and deep bed. Two HFF filter units purify 33% of the full condensate flow. Each filter unit has an approximately 7,000 m^2 filtration area. Filter vessel is 2,100 mm in diameter and 6,000 mm in height.

TABLE II

Condensate Polishing System Specification (1F-3)

Condensate Flow Rate (m^3/hr)	4450
Condensate Filter Type	HFF
Capacity(m^3/hr)	1550(33%)
Total Filtration Area(m^2)	14000
L.V.(m/hr)	0.1
Number of units	2
Vessel size(mm)	2100
(Diameter x Height)	x 6000
Condensate Demineralizer Type	Deep Bed
Capacity(m^3/hr)	4450
Number of units	8(1)

Figure 5 shows ΔP-time characteristics of the replaced hydrophilic HFF. It can be seen from this figure that the initial ΔP and ΔP rising rate have the same features as that obtained from the pilot scale test. The initial ΔP value was 0.24 Kg/cm^2 at the beginning of operation and 0.28 Kg/cm^2 before the first back-wash operation. The ΔP increased only 0.04Kg/cm^2 for *160* day operation and the accumulation of suspended solids was about 6.6g per unit filter area(m^2).

Same type hydrophilic HFF has also installed in the radwaste systems and shown excellent operation, as observed in the condensate polishing system. In the future, the conventional HFF which requires replacement, will be replaced by this hydrophilic HFF.

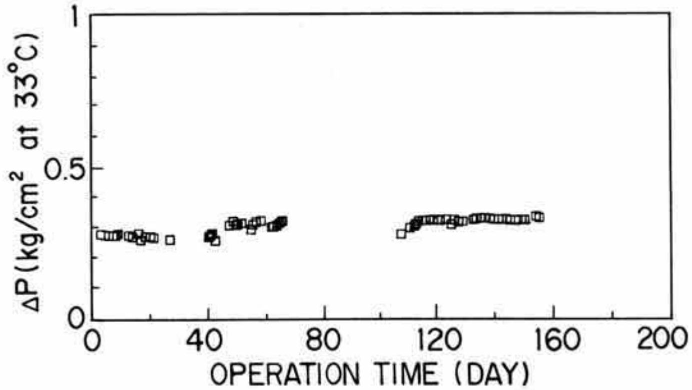

Fig. 5. Variation of ΔP with operation time.(1F-3)

CONCLUSION

The hydrophilic HFF was prepared by impregnating hydrophilic monomer in a conventional HFF followed by polymerizing. This hydrophilic HFF has the following features.

1. Handling is far more easy compared with the conventional HFF.

Thus, the package weight of a module was reduced to one-third.

2. Initial ΔP value decreased. The initial ΔP was reduced to about 70% of that for the conventional HFF.

3. Slow ΔP rising rate value was obtained.

The ΔP rising rate was reduced to about 70% of that for the conventional HFF evaluating the results of the pilot scale test.

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